NOTICES

This technical paper is issued to disseminate timely, useful technical data to activities engaged in photogrammetry, cartography, geodesy and related subjects. Nothing in this paper should be construed as establishing USAF doctrine.

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ILLUSTRATIONS

ABSTRACT

This paper describes experiences at ACIC obtained with the AP-2 Plotter. It discusses the basic concepts upon which the AP-2 Plotter operates, some key tests performed, problems associated with its introduction into a mapping organization and evaluates the plotter in respect to contemporary instrumentation. Emphasis in technical discussion is placed upon the capability of the plotter to remove systematic distortions arising from random and non-random sources.

This instrument represents a great advancement in photogrammetric instrumentation, but in its present form should not be expected to reduce operational time significantly in bridging and compilation operations. The AP-2 allows more complete exploitation of photogrammetric materials but because of its complexity and increased requirements for advanced personnel training, it will not be easy for most organizations to incorporate it in their line operations.

Operational Use of the AP-2 at ACIC

I. INTRODUCTION

1. Introduction

The AP-2 Analytical Plotter was delivered to ACIC 6 July 62. Since that time, we have been busy testing this instrument and training people in techniques and concepts for its application in an operations environment. Our experience with the AP-2 is the subject of this paper and will cover the following areas of interest:

a. Operation Tests
b. Problems associated with operation of the AP-2
c. Evaluation of the AP-2 compared to conventional instrumentation.

It is believed that the information to be presented will help place the AP-2 in proper perspective so that realistic estimates of its performance and capability can be predicted.

II. BACKGROUND

2. Functional Description of the AP-2

Before getting too deeply committed to the technical details of this talk, it is worthwhile to spend a few minutes discussing the AP-2 from an operator's point of view.

Figure 1 is a picture of the AP-2. Mechanically, an operator has three modes of controlling the machine's operation: through the console; through the tape reader; and through the foot and hand wheels.

Conceptually, the AP-2 computer can be broken down into two computers. (See Fig 2) The DDA computer continually operates at the rate of one complete computer cycle every 10 milliseconds. During each cycle it receives quantized bits of 5μ from each of the (X_m, Y_m, Z_m) foot disc or hand wheels, transforms them, corrects for various systematic distortions, and outputs its corresponding movement (Δx, Δy) to each of the comparator tables and to the plotter table. During the various steps in the DDA computations, constants data is drawn from the General Purpose Computer (GPC) and new data stored back again as it is developed. Each DDA cycle is broken up into 80 word times and up to four digital computations can be performed during each word time

The GPC controls the constants input, modification and read out of the instrument. As seen in the figure, it is only through the GPC that the operator can control the response of the freely cycling DDA

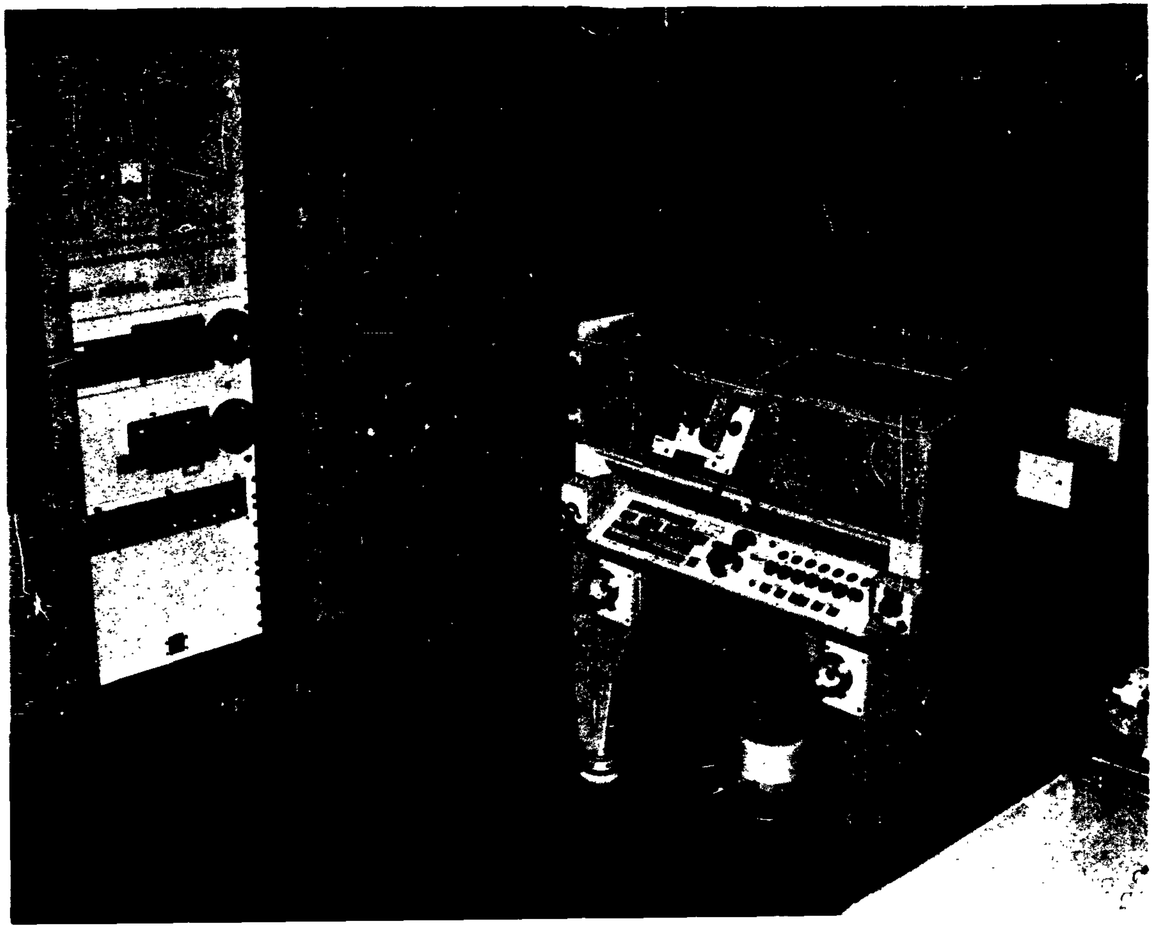


Figure 1 **AP-II** Plotter and Computer

CONCEPTUAL DIAGRAM OF BASIC AP-2 OPERATION

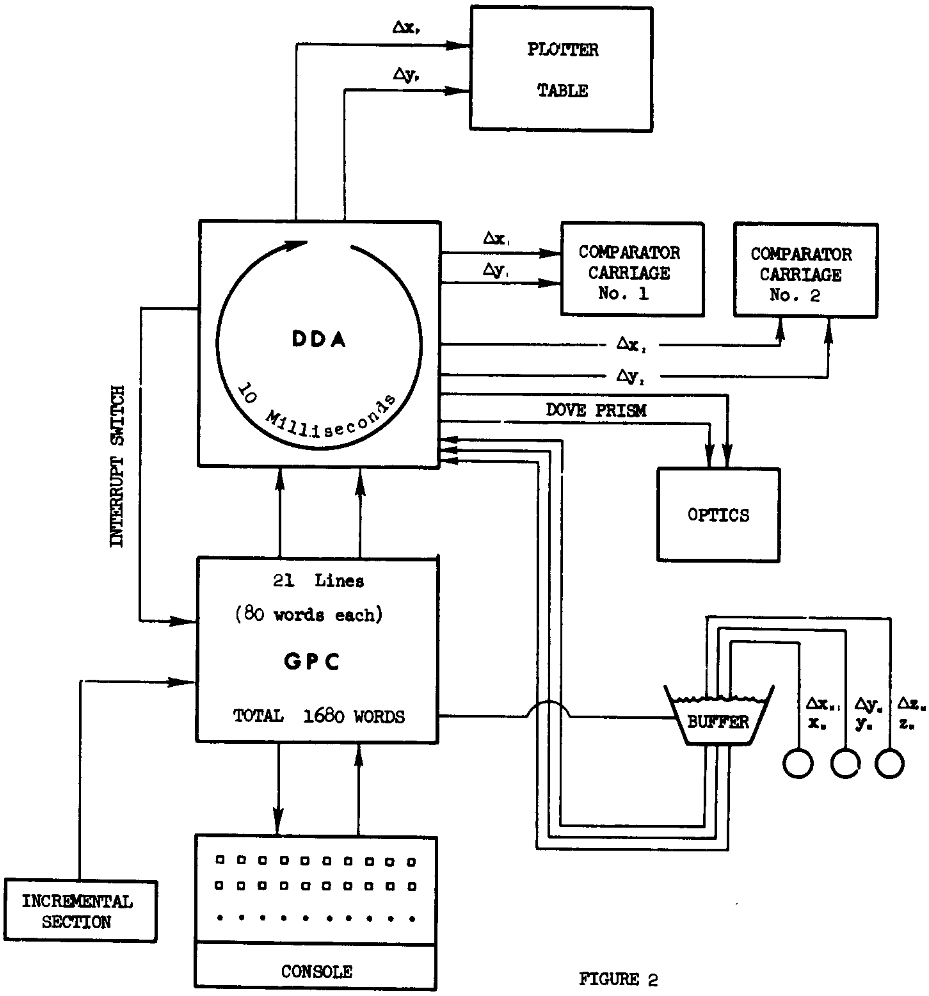


FIGURE 2

computer to movements of the hand wheels and foot discs. To exercise this control, the operator depresses desired switches on the console which the GPC recognizes as break point settings to direct its programming for readout or input.

Each time the DDA completes 1 cycle, it resets a reader interrupt switch which causes the GPC to interrogate the console and enter a related program. Depending upon the program selected, the GPC will readout data, modify constants storage, or enter new data.

Figure 3 is a close up picture of the AP-2 command console. The upper row of switches relate to inputs and outputs for basic operations (e.g. interior orientation, absolute orientation, constants input, etc.) and the photo to which they apply. Input and readouts related to orientation and model readout are controlled by the second row of switches. The third row of switches control input and readout of basic calibration constants associated with each photograph. The bottom row of switches contain start switches to initiate the GPC to: input and display data, read in punch tape; perform interpretive operations related to interior, relative and absolute orientation; or to disconnect comparator tables from computer drive so that interior orientation can proceed.

3. <u>AP-2 Ranges of Operation</u>

The AP-2 is unique compared to present contemporary instruments in that it is a truly universal plotter, capable of being programmed to handle any type of photo, either whole or partial with any format. The machine is limited only by the program under which it is controlled. To meet Air Force requirements, the AP-2 instrument at ACIC is programmed to handle either frame and panoramic materials limited by the following:

Whole or partial format:	9" x 9"
f:	<48 inches
Angle of viewing off principal axis:	<60° frame
	<45° panoramic

The instrument has the following mechanical characteristics:

Bit increment from plotter hand wheels =	5μ
Slew speed =	20 mm/sec. max.

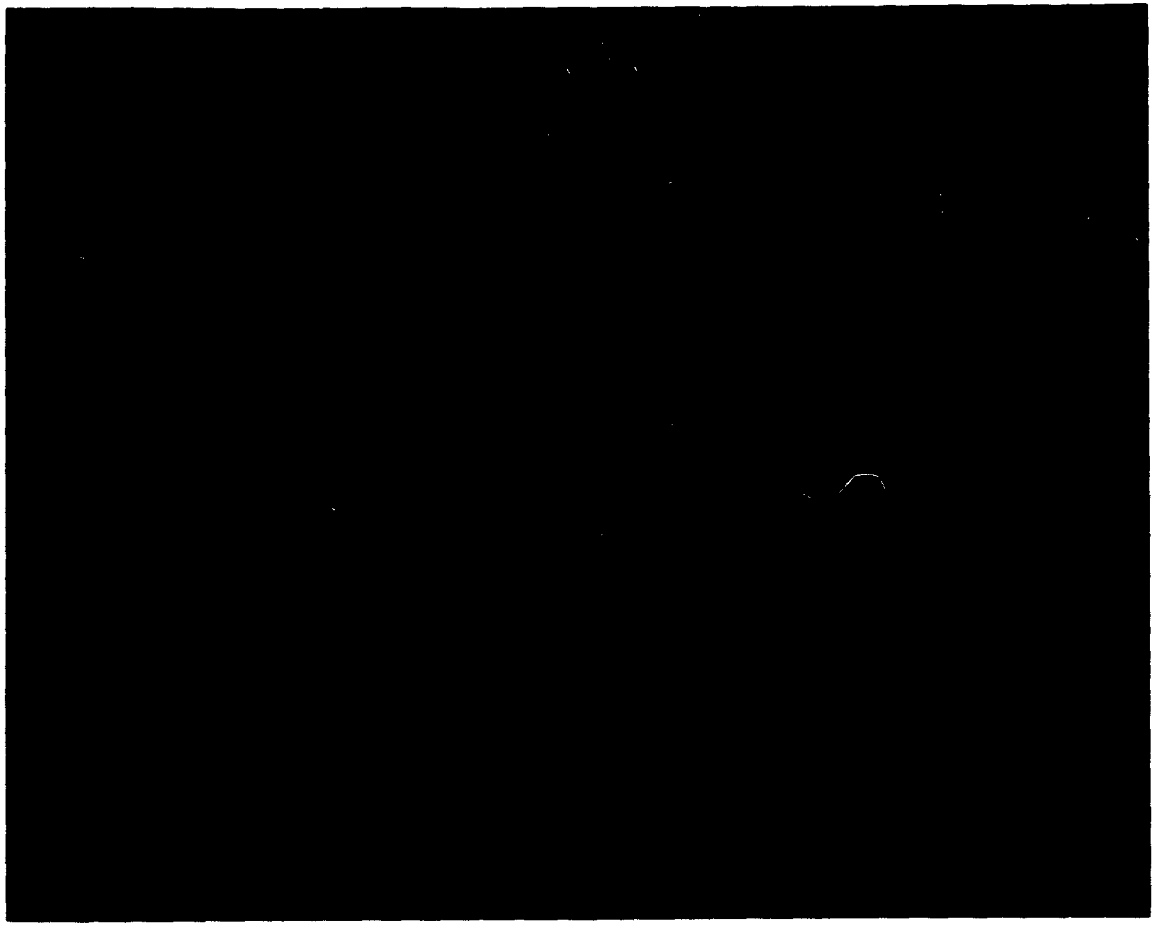


Figure 3 **AP-II Command Console**

Optical magnification = 6x, 10x (14x variable to 28x)

plotter scales = 0.5x to 30x at 25°/∘ increments between steps

Maximum model to photo scale = 12.25°/∘

plotter table dimensions = 1360 x 1060 mm

plotting coordinates = XY, XA, YZ, and X or Y

There are other features of a more detailed nature but which are not important for the substance of this paper.

4. Safety - Error Features of the AP-2

The AP-2 is more fool proof in its mechanical operations than a contemporary type instrument. No combination of quantity values which result in a photo point going beyond the limits of machine motion are permitted while the comparator tables are connected to computer outputs. It is also impossible to enter data which will cause the comparator table run to exceed machine limits. If such data is entered from the console while outputs are connected to the comparator tables, correction is made until the machine reaches a limit switch after which it returns to its original state. If input is made through the hand wheels or foot disc, the comparator table is disconnected when mechanical limits are reached. If input is still continued, the computer will continue to accept data but the relation between the computer and the comparator tables is destroyed. Before this situation occurs, however, a warning signal is given so that the operator can cease his motion.

5. Operations Which Can be Performed on AP-2

The AP-2 can perform any operation capable of being done on a conventional analog machine. It is easy to operate, so much so that after interior orientation and storage of constants into the computer, a fully trained analog operator would find little difficulty in applying the usual analog techniques of orientation and plotting used on conventional instruments. If he is an imaginative person, he will find this instrument makes it convenient for him to perform these functions more easily by allowing him to drive directly to selected positions to observe parallaxes and make other desired settings. In addition to the analog techniques the machine allows the use of an automatic 6 point parallax least squares solution for relative orientation. This solution for whole frame photos converges quite rapidly to the point where an operator wishes to take over to make final adjustments to the model.

A similar automatic feature is provided for absolute orientation in which the operator makes observations in the model, enters point coordinate data, punches a button and the plotter automatically solves and corrects stored constants for all changes to the elements of absolute orientation by the method of least squares.

Its ability to change instrumental and constant settings is similar in principal to conventional instruments. The numerical nature of these settings allows for convenient application of numerical techniques for doing relative and absolute orientation of partial models involving high correlation between the elements of orientation.

6. Systematic Error Correction in the AP-2

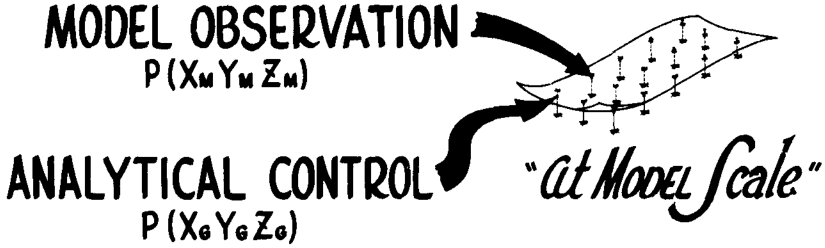
The AP-2 has considerable power and flexibility in the manner in which it can take into account various sources of systematic error, both known and unknown. As seen from Figure 3, the AP-2 console has several switches for entering constants to remove the effects of:

a. Differential film shrinkage
b. Vehicle motion and IMC errors
c. Earth curvature and refraction

In addition it is also possible to enter constants data into or through the GPC computer which are used by the DDA computer to remove the effects of lens distortion and to map model coordinates into a desired map projection on the plotting table.

To take care of unknown systematic errors caused by such things as errors in relative orientation, incomplete knowledge of lens and camera calibration, vehicle motion, etc., whose effects cannot be eliminated during absolute orientation, the AP-2 has designed into it what we at ACIC refer to as the Black Box capability. It consists of special programming in the DDA section to allow warpage of the stereo model in the three coordinate directions in accordance with a set of three cubic polynominal formulae each containing the 9 terms. The coefficients for these formulae are developed off line to the plotter and are based upon the comparison between stereo model coordinates and given control coordinates. Observations are reduced by the least squares method and the solved coefficients are taken and entered through the GPC to be stored in and used by the DDA computer. The choice of coefficients to be solved is completely arbitrary and may be such that the correction formulae can have either conformal or non-conformal properties as desired. Figure 4 is a graphic representation of how this is accomplished.

Model Deformations "XYZ"



BLACK BOX

$X_M Y_M Z_M$ $\qquad$ $X_G Y_G Z_G$

$$\Delta X = a_0 + a_1 X_M + a_2 Y_M + a_3 X_M Y_M + a_4 X_M^2 + a_5 Y_M^2 + a_6 X_M^2 Y_M + a_7 X_M Y_M^2 + a_8 X_M^3 + a_9 Y_M^3$$

$$\Delta Y = b_0 + b_1 X_M + b_2 Y_M + b_3 X_M Y_M + b_4 X_M^2 + b_5 Y_M^2 + b_6 X_M^2 Y_M + b_7 X_M Y_M^2 + b_8 X_M^3 + b_9 Y_M^3$$

$$\Delta Z = c_0 + c_1 X_M + c_2 Y_M + c_3 X_M Y_M + c_4 X_M^2 + c_5 Y_M^2 + c_6 X_M^2 Y_M + c_7 X_M Y_M^2 + c_8 X_M^3 + c_9 Y_M^3$$

$$(X_M) = X_M + \Delta X$$

$$(Y_M) = Y_M + \Delta Y$$

$$(Z_M) = Z_M + \Delta Z$$

Effect of Coefficients on Observed Model

Adj. $\Delta X = a_0 + a_1 X_M + a_2 Y_M + a_3 X_M^2 \ldots\ldots + a_9 Y_M^3$

Adj. $\Delta Y = b_0 + b_1 X_M + b_2 Y_M + b_3 X_M^2 \ldots\ldots + b_9 Y_M^3$

Adj. $\Delta Z = c_0 + c_1 X_M + c_2 Y_M + c_3 X_M^2 \ldots\ldots + c_9 Y_M^3$

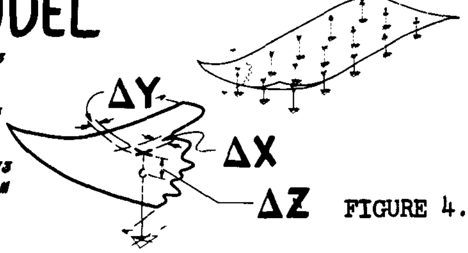


FIGURE 4.

III. TESTS

7. Introduction

Tests conducted by ACIC were directed towards investigating the following:

a. Determine the basic precision of the AP-2 mechanisms.
b. Study the accuracy of AP-2 computations based upon given constants.
c. Bridging
d. Compilation
e. Black Box Capability

8. Mechanical Tests

Mechanical tests of the AP-2 were designed to determine the following:

a. Accuracy of the plate carriage movement.
b. Accuracy of the plotting table.
c. Model flatness.

No errors in calibration were assumed for these tests.

8.1 Plate Carriage Tests

The plate carriage tests were performed using a 2 1/2" x 2 1/2" square grid with a line spacing of 2 1/2 mm. Each line of the grid was 5μ wide and each grid intersection was calibrated to within 2μ.

The test consisted of placing the grid in each carriage and reading out the photo x, y plate coordinates of a distributed set of intersections at the console of the instrument. A linear conformal adjustment of the observed data to the calibrated grid data was made with the following unit standard radial observation error.

$$\sigma_L = 5\mu \text{ (Left carriage)}$$

$$\sigma_R = 4\mu \text{ (Right carriage)}$$

It was concluded, there was no significant difference between the precision of the two carriages with respect to the count readout of .01 mm at the console.

8.2 Plotting Table Tests

Using the same set up as for the plate carriage tests, a plot of the grid intersections was made on the AP-2 coordinatograph at a scale

of 2:1 on stable base material. The plotted intersections were measured on the coordinatograph of a Wild A-7 which was assumed to have a radial standard error of 10μ.

A conformal adjustment of the measured data to the calibrated grid data was made with a unit radial standard error of 15μ at original grid scale. This standard error has been corrected for the effects of inaccuracy of the Wild A-7 coordinatograph and it reflects the total combination of errors of the carriages plus the plotting table mechanism.

8.3 Model Flatness Tests

Model flatness tests were conducted with 9" x 9" Wild grid plates scribed with 15μ line weight lines. Model parameters were:

focal length = 150 mm

forward lap = 60°/o

Exposure Station elevation
above datum ≈ 150 mm

Observations were made in the model at 15 mm intervals and recorded at the console. The following unit standard errors were obtained in plan and elevation after conformal adjustment to the known calibrated coordinates of a theoretically flat model.

$\sigma_p = 6.4\mu$ (radial standard error)

$\sigma_h = 9.9\mu$

These results reflect a precision C factor of C ≈ 4600.

9. Constants Tests

These series of tests were to determine the numerical computation accuracy of each of the correction functions as computed in the DDA computer. Each test was performed using the previously mentioned calibrated Wild Plates in each of the plate carriages. Machine coordinates read from the console were compared against theoretically computed coordinates to determine accuracy of compensation. Summary results of the tests performed are shown in Table I.

Tests No. 1 and 4 were conducted on the basis of single 9" x 9" format.

Tests No. 2 and 3 were conducted assuming a stereo model having the following characteristics:

TABLE I

Results of Correction Function Tests

Maximum Systematic Error

TESTS		RESULTS
1. Differential Shrinkage		not significant
$0.1\ ^{\circ}\!/_{\circ}$	10μ	non linear over correction
$0.5\ ^{\circ}\!/_{\circ}$	40μ	
2. Earth Curvature	14μ (elevation)	
3. Atmospheric Refraction	20μ	systematic over correction with max. at center of model.
4. Lens Distortion	15μ	

$$Sm = 1{:}100\ 000$$

$$f = 150\ mm$$

$$\text{forward lap} = 60\%$$

10. Bridging Tests

All bridging tests were made using calibrated grids. The idea here was that if precision could be maintained with grids, any further degradation in practice would be due to the nature of materials used and not rightly attributable to the AP-2. Viewing optics capability was not questioned.

The test performed consisted making a 6 model cantilever using 9" x 9" Wild grid plates. Model space coordinates were recorded and the strip was adjusted to theoretical grid values by an analytical process based upon conformal plane and vertical polynominal equations. The unit standard errors after adjustment were as follows:

$$\sigma_x = 7\mu$$

$$\sigma_y = 9\mu$$

$$\sigma_z = 10\mu$$

Model parameters for this triangulation were:

$$f = 150\ mm$$

$$Z = 150\ mm$$

$$\text{forward lap} = 60\%$$

Time limitations to date have prevented us from pursuing these investigations further for longer extensions using different restraint conditions.

11. Compilation Tests

Compilation tests were performed using real materials and consisted of two parts:

a. Spot height measuring tests
b. Contouring evaluation tests

11.1 Spot Height Measuring Tests

A pair of overlapping photographs taken over the Arizona Test

Area were selected for this test. The photographic parameters for this material are as follows:

focal length = 154 mm

altitude = 13, 900 meters

camera = T-11 with metrogon lens

scale - 1:91 230

Base/Height ratio = 0.45

A nominal Metrogon lens distrotion curve was assumed for the purpose of this test.

Height measurements were made for 45 points for which ground survey data is available.

These measurements were subjected to a linear of adjustment to establish the basic distortion pattern in the stereo model and to determine an estimated pointing accuracy of the instrument over a significant portion of the model area. The unit standard error after adjustment was:

σ_p = .7 meters (radial standard error)

σ_h = 4.8 meters (52μ at model scale)

Inspection of the residual errors after this adjustment revealed a systematic vertical deformation of the model surface. A graphic portrayal of the nature of this deformation is given in Figure 5. The entire model was then subjected to a vertical adjustment which would remove the effects of second degree surface deformations. The unit standard error of this adjustment was:

σ_h = 2.8 meters (31μ at model scale)

Inspection of the errors remaining after this adjustment still indicate residual systematic surface deformation which is graphically portrayed in Figure 6. The upper and lower halves of the model were subjected to independent vertical adjustments with residuals as shown in Figure 7 with the following unit standard error:

σ_h (upper) = 2.3 meters (25μ at model scale)

σ_h (lower) = 1.4 meters (15μ at model scale)

The lower half contained about 30 of the 45 points.

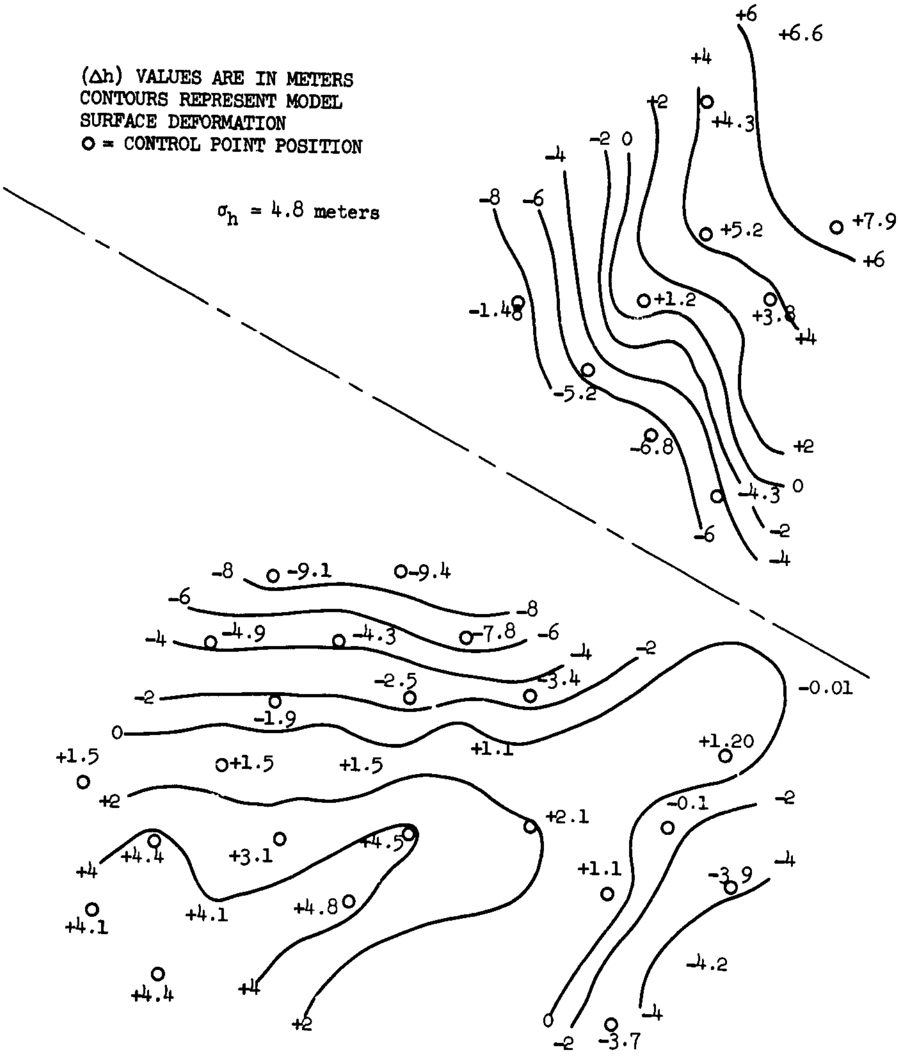


FIGURE 5. BASIC ELEVATION DISTORTION PATTERN OF THE ARIZONA TEST MODEL.

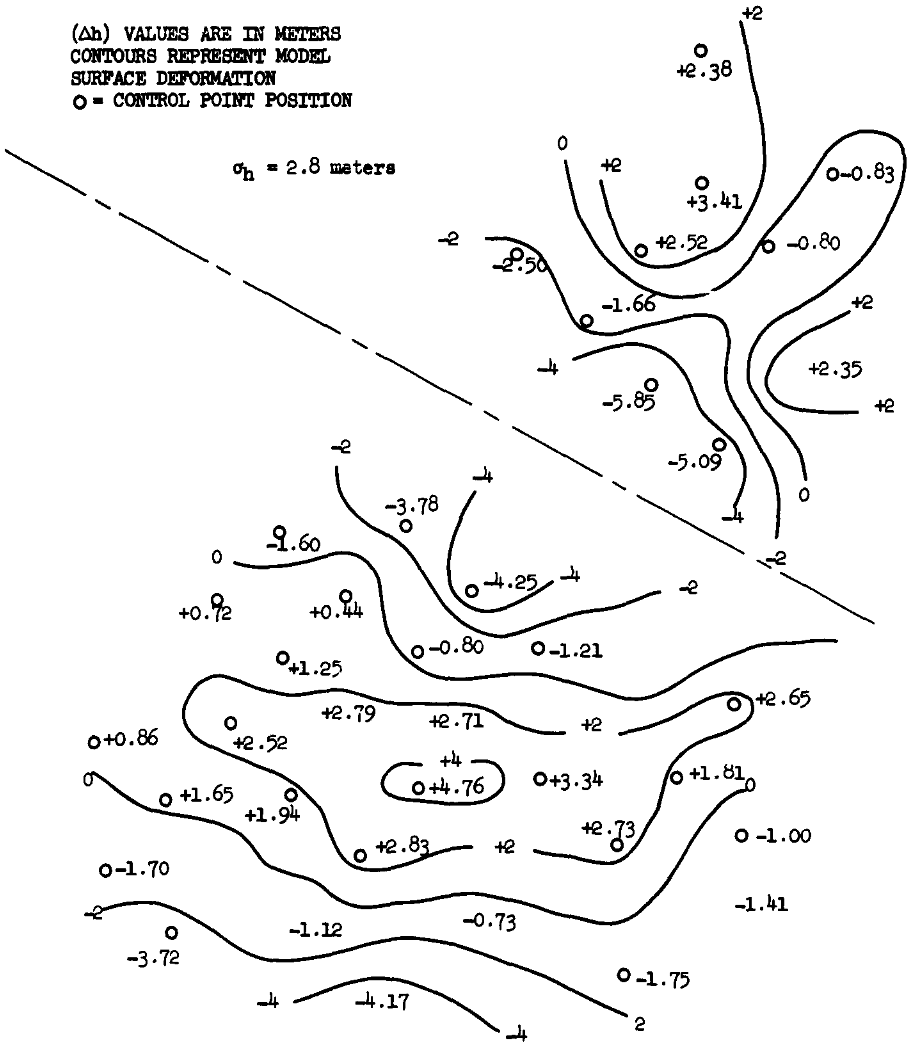


FIGURE 6. RESIDUAL ELEVATION DISTORTION AFTER PARABOLIC ADJUSTMENT (TO REMOVE EFFECTS OF SECOND DEGREE SURFACE DEFORMATION)

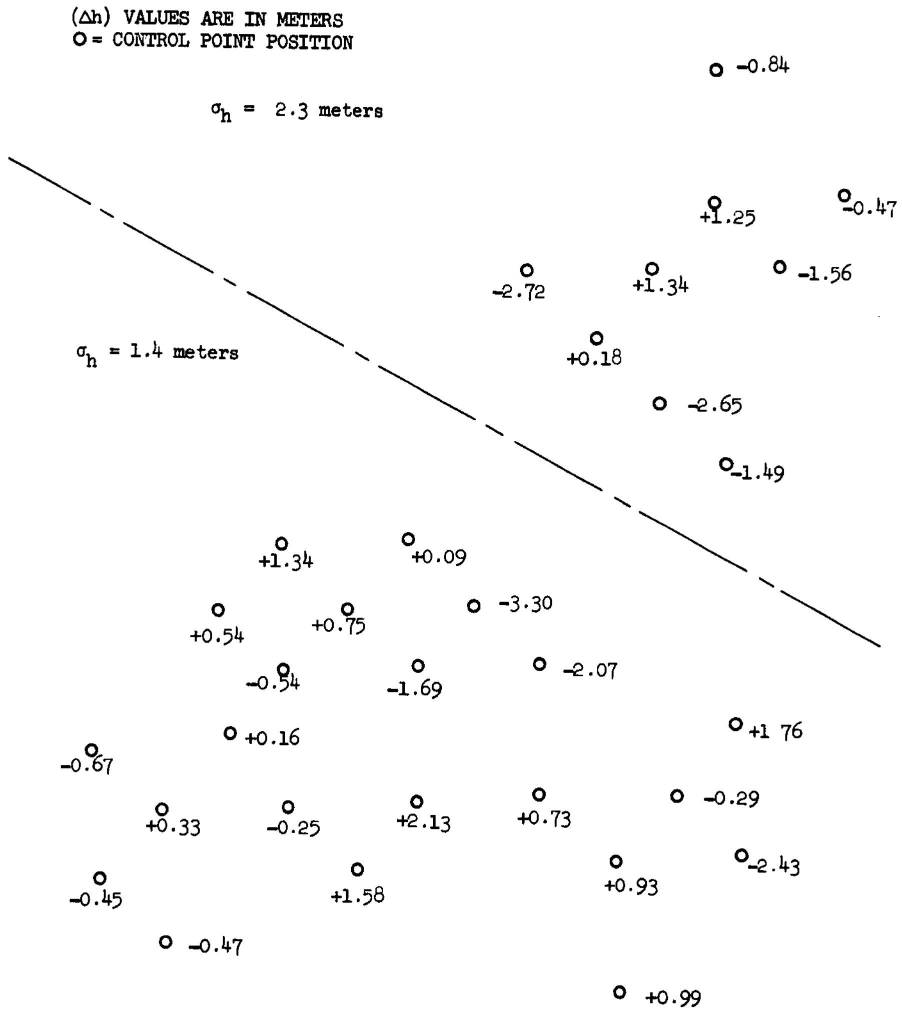


FIGURE 7. RESIDUAL ELEVATION ERROR PATTERN AFTER FINAL ADJUSTMENT OF UPPER AND LOWER HALVES. (ARIZONA TEST MODEL)

The residual errors after this final adjustment showed no significant systematic error patterns like the previous adjustments. They also indicate that with full compensation for systematic error, the AP-2 should be able to compile contours with a C factor in the range of $C \approx 2500$ using materials flown with a 6" focal length camera at 60% forward overlap.

<u>Summarizing this Test</u>, the analysis of the results of the linear adjustment revealed the character of overall model deformation. A second degree adjustment removed the gross non-linear systematic errors due to other unknown effects such as possible residual earth curvature, errors in orientation, etc. Analysis of the results of this adjustment indicated some remaining systematic surface deformation of unknown origin.

This remaining error might have been caused by differential film shrinkage or other physical defects of the diapositives. The history of these plates is unknown. After partial model adjustments were performed, residual errors were reduced to approximate randomness. These tests indicate the degree of degradation of heighting accuracy that can be introduced by the photographic materials themselves over and above what is removed in the absolute orientation process. It is tests such as these that justify the need for a Black Box capability of which more will be said later in this paper.

11.2 Compilation Tests

Planimetric capabilities have been tested which show that the viewing system is quite adequate for discerning planimetric features to within the mensuration capability of the instrument. Contouring tests using materials equivalent to those obtained from 6" focal length cameras flown vertically with a forward overlap of 60% have given a spread of C factors from 1000 to 2000. These compared quite favorably with similar tests using the same materials on an A-7. On the basis of such tests the conclusion was reached that under operational conditions, both instruments were equivalent. Further tests are planned which will establish the upper limits of this machine when its Black Box capability is employed fully.

12. <u>Black Box Tests</u>

Black Box Tests were designed to test the precision with which the Black Box Program could eliminate random non-linear distortions in an AP-2 stereo model. The tests performed were:

a. Test the numerical precision of the Black Box Program.
b. Test the accuracy of adjustment using real data.

12.1 Numerical Precision Tests

In this test a grid model was formed to simulate a frame photograph model. The coordinates of each grid intersection were analytically deformed using a set of non-conformal third degree polynominal distortion equations in X, Y and Z. The coefficients of these polynominal equations were fed as constant data into the Black Box Program and the instrument deformed model was compared to the analytical deformed model. Figure 8 shows the magnitude of deformed data used in this test. As you can see, large distortions were introduced. Figure 9 shows the residual model distortions remaining after the Black Box adjustment of the model to the theoretical distorted values. The unit standard error of residuals after adjustment was:

$$\sigma_x = 11.9\mu$$

$$\sigma_y = 11.5\mu$$

$$\sigma_z = 23.0\mu$$

12.2 Black Box Adjustment of Panoramic Materials

The computational precision test proved the capability of the AP-2 to compensate for extreme non-linear distortions. An interesting application of this capability was to remove the distortions. An interesting application of this capability was to remove the distortions from a stereo model constructed using stereo pan materials taken at comparatively high altitude over Shaw AFB, Alabama. The camera employed for these tests was the KA 52 panoramic system having the following characteristics:

f = 75 mm

scan angle = 180°

format = 4 1/2" x 12"

cycling ratio = 6 cycles/sec.

resolution = 70 lines/mm

Two exposures having common overlap and a convergent angle of 30° were selected over a well mapped area in the vicinity of Shaw AFB. After setting up a 2x enlarged portion of the stereo pan model in the AP-2 and orienting it absolutely to map control the residuals shown in Figure 10 at model scale were obtained. Several adjustments were made to determine the best set of coefficients for the Black Box Program. The final set of non-conformal equations selected were of the form:

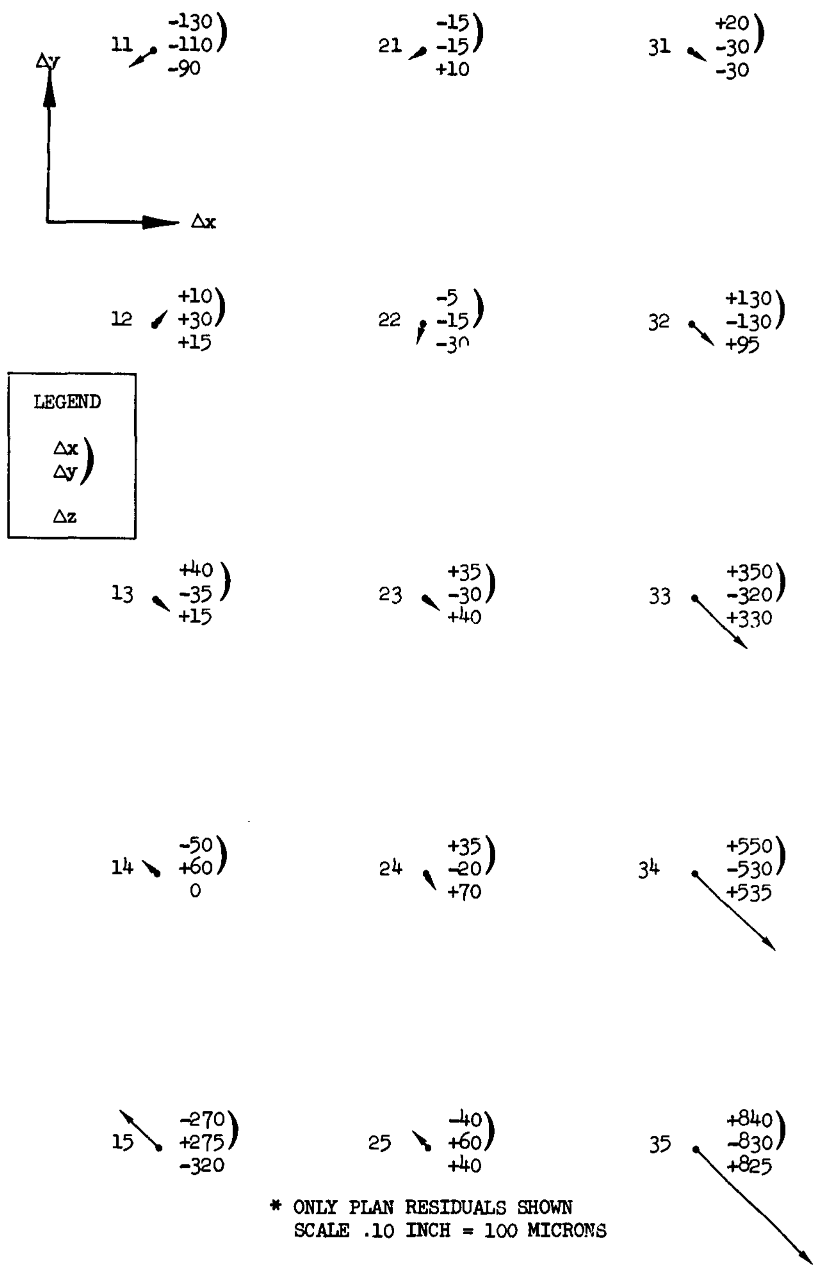
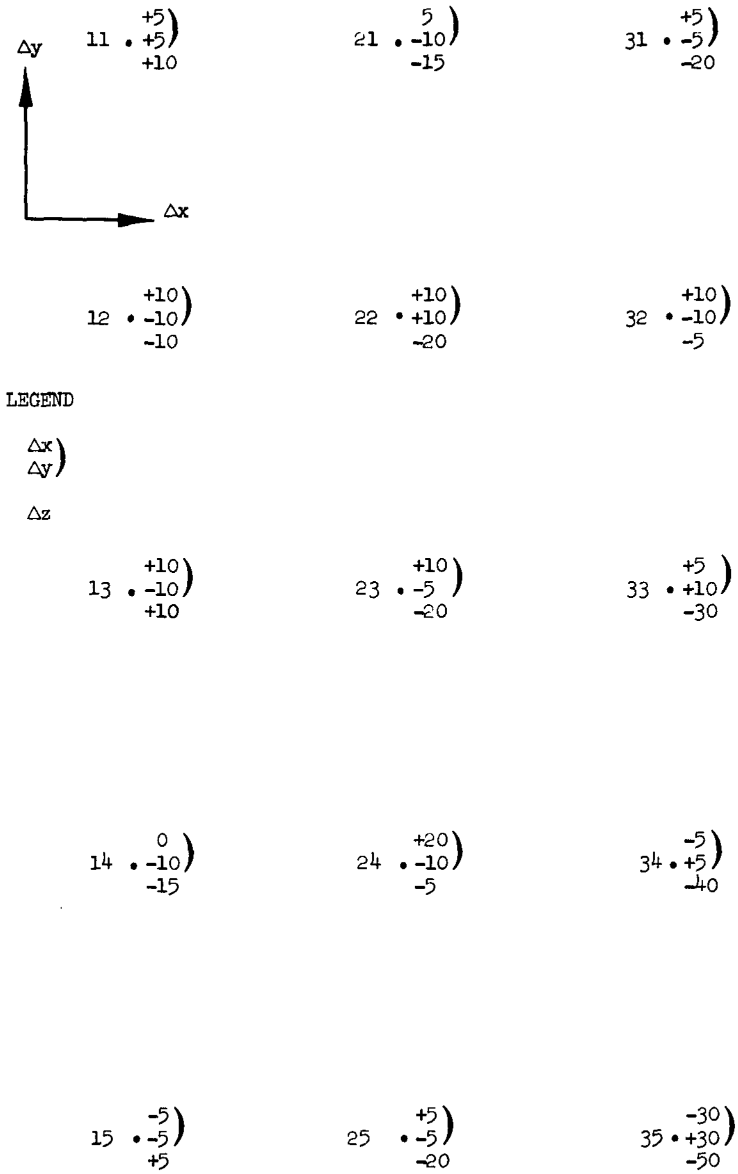


FIGURE 8. SIMULATED DISTORTION OF A FRAME MODEL USED IN BLACK BOX PROGRAM PRECISION TEST.



NOTE: AT SCALE OF .10 INCH = 100 MICRONS, PLAN RESIDUALS ARE SO SMALL THEY COULD NOT BE PLOTTED.

FIGURE 9. RESIDUAL DISTORTION OF A FRAME MODEL AFTER CORRECTION IN BLACK BOX PRECISION TEST.

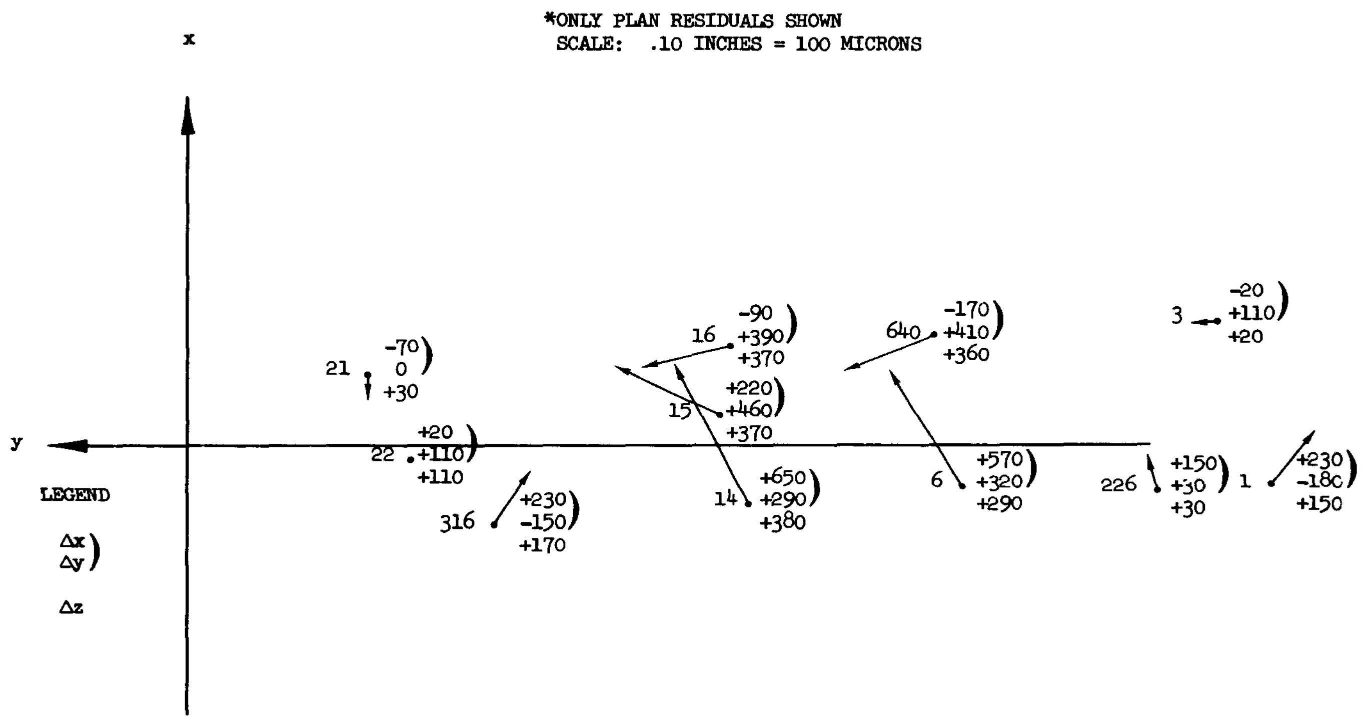


FIGURE 10. PANORAMIC MODEL RESIDUALS WITH RESPECT TO MAP CONTROL BEFORE BLACK BOX ADJUSTMENT

$$\Delta x = a_0 + a_1 x + a_2 y + a_3 xy + a_4 x^2 + a_5 y^2 + a_7 xy^2 \quad : \sigma_x = 71\mu$$

$$\Delta y = b_0 + b_1 x + b_2 y + b_3 xy + \qquad b_5 y^2 + b_7 xy^2 \quad : \sigma_y = 88\mu$$

$$\Delta z = c_0 + c_1 x + c_2 y + c_3 xy + \qquad c_5 y^2 + c_7 xy^2 \quad : \sigma_z = 41\mu$$

The residuals obtained as a result of this adjustment are shown in Figure 11. Considering the nature and sources of distortion in panoramic materials, these results are quite good and represent a significant reduction. Without the Black Box capability such photography would be unusable for general topo map compilation class A standards - with it a new area of photographic exploitation is opened up.

13 Problems Associated with AP-2

The AP-2 has several problems associated with it when attempts are made to integrate it into an operational organization. They may be categorized as follows:

a. Initial tape preparation
b. Environment
c. Maintenance
d. Training
e. Computer integration

Tape preparation problems are due to the fact that the AP-2 works with three different tape formats - two input and one output. The two inputs are unique to the computer and not directly translatable from standard flexowriter type equipment. The most efficient way of handling this problem is to prepare AP-2 tapes by a means of translation and tape preparation routines on auxiliary computing equipment. Special programming to accomplish such preparation has been completed at ACIC.

The need for special environment for the AP-2 needs little explanation. This is a precision mensuration device with a great deal of electronics associated with it. Temperature and humidity control to within a few degrees and percent points is a must along with power free from line fluctuations. Considerable planning and effort had to be expended in ACIC for site preparation for the AP-2.

Associated with the problem of environment are the problems of maintenance. Table II is a sample of the down time and maintenance accrued with the AP-2 over several months period of time. With experience the up time on this equipment is improving but we expect always to have a need for maintenance even after it outgrows its present prototype stage.

*EXCEPT WHERE INDICATED, PLAN RESIDUALS ARE TOO SMALL
TO BE SHOWN AT A SCALE OF .10 INCHES = 100 MICRONS

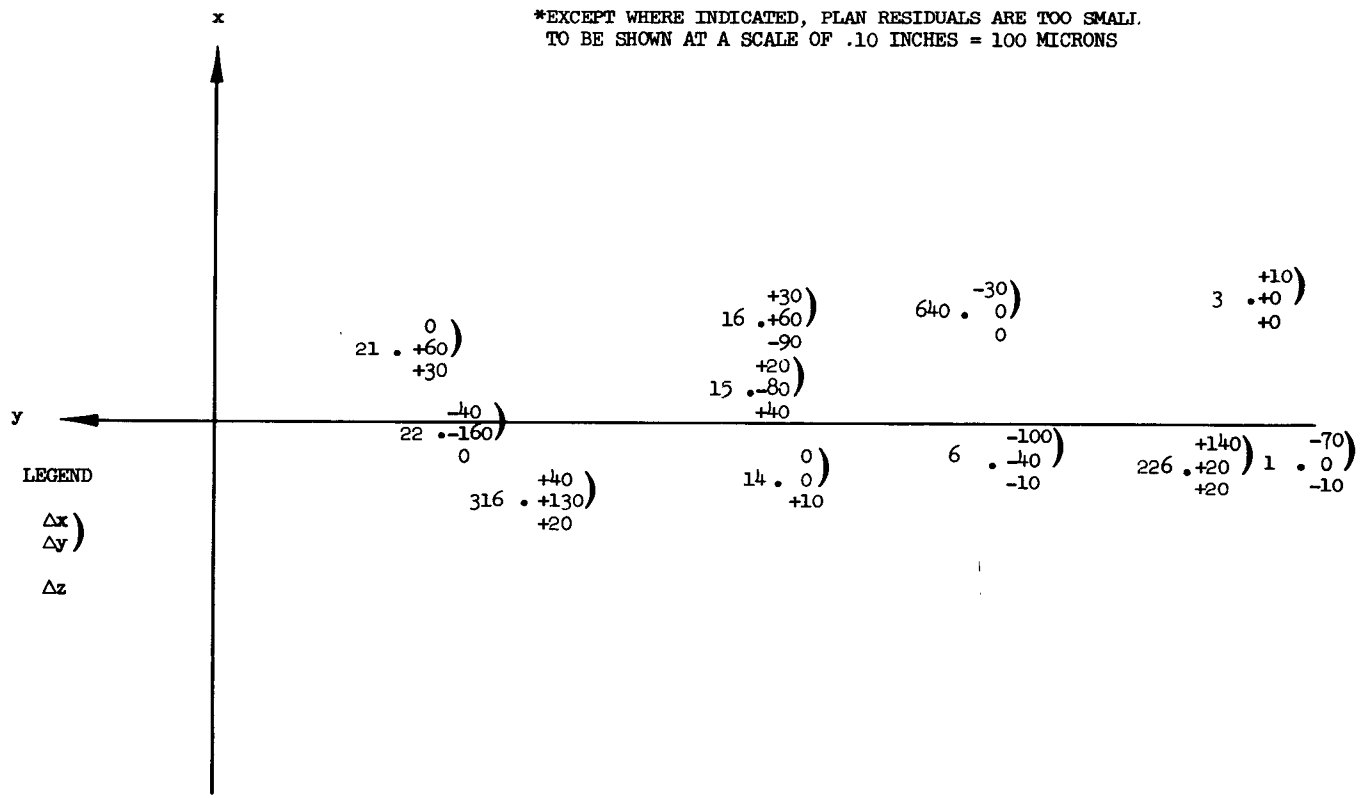


FIGURE 11. PANORAMIC MODEL RESIDUALS AFTER BLACK BOX ADJUSTMENT

TABLE II

AP-2 Up - Down Time Record for 1962 - 63

	WEEK	UP	DOWN	TOTAL SCHEDULED TIME	°/. DOWN TIME
Dec	3 - 7	32	8	40	25
	10 - 14	29	11	40	34
	17 - 21	48	0	48	0
	26 - 28	17	7	24	41
	31 - Jan 4	26	6	32	23
Jan	7 - 11	64	0	64	0
	14 - 18	46	2	48	4
	21 - 25	29	11	40	34
	28 - Feb 1	32	8	40	25
Feb	4 - 8	40	0	40	0
	11 - 15	23	17	40	74
	18 - 21	32	0	32	0
	25 - 28	56	8	64	14

*This does not account for time lost searching for errors or to redo work.

Personnel training problems are more critical with this type of equipment for two reasons. First the operator must be familiar with computer operation as well as the photogrammetric operations of the instrument. Second, most efficient exploitation of this instrument is achieved by a proper blending of numerical and analog techniques. More than ever, an operator must be familiar with analytical photogrammetric theory - a requirement formerly reserved only for key first order instrument operators in a line organization.

To make maximum utilization of the Black Box Program, an auxiliary computer system must be available capable of computing the least squares solution for its coefficients. This involves computer scheduling problems to make such computations in a timely manner.

14. Operations Performance Factors

With the experience acquired so far at ACIC several statements can be made about expected performance of the AP-2 in future operations.

As far as basic precision is concerned, the present AP-2 prototype does not equal the precision of say the Wild A-7. Witness the basic AP-2 grid test precision of $C \approx 5000$ as opposed to $C \approx 10\ 000$ for an A-7 model magnification of 2:1. (The disparity is due to the difference in model magnification scale.) This limitation on basic precision is electronic in nature and can be improved by decreasing the basic 5μ increment to 2 1/2μ off of the hand and foot wheels at the expense of slew speed. On the other hand, when working with average wide angle cartographic materials, the AP-2 performs as well as the A-7. Consequently, it is our opinion that under normal conditions the AP-2 will perform with the same accuracy as present available first order equipments.

In the comparison of operation times to conventional instrumentation, the AP-2 does not show any significant advantages. What is gained in the use of its automatic features in relative and absolute orientation is lost in computer set up and tape preparation. Also, the need for operator judgment is not eliminated with such automation. Since the least squares process of relative orientation pre-supposes a given math model, it is still the responsibility of the operator to determine any deviations from the model and improve his solution accordingly. If the Black Box solution is used, actual model set up time may take longer than present procedures but with an accompanying improvement of accuracy.

As far as compilation time is concerned, no improvement in time is expected since procedures on the AP-2 will parallel what is presently being done on conventional instruments.

IV. DISCUSSION

15. Discussion

The AP-2 represents a significant advance in stereophotogrammetric instrumentation. In its approach to the photogrammetric problems, it is a universal instrument able to handle any kind of camera material with first order accuracy regardless of its format, focal length, tilt and calibration characteristics. With its Black Box capability, it can make fuller use of ground survey data to overcome operator error in relative orientation and lack of calibration data.

The AP-2 in its present form should not be expected to reduce operator time significantly in bridging and compilation. These operations are limited more by judgement and decision making operations than by the instrument operations.

The AP-2 allows an advance in the concepts of utilization of the general body of photogrammetric materials. In the past, current photogrammetric practice has been to call for the use of special calibrated, relatively distortion free, camera materials for control extension and compilation. Unfortunately to obtain distortion free materials we have invariably compromised resolution. Because of its capabilities for removing known and unknown distortions, and to partition photographs which have been photographically processed to extract every bit of information which their resolution can support, the AP-2 can take advantage of existing higher resolution systems whether they are based on panoramic, slit, or conventional frame geometry. Higher resolution systems go hand in hand with high flying, high performance aircraft. The gains to be achieved through increased coverage taken from the more stable flight platforms afforded by such high flying systems will cause us to throw away many of the rules we have been operating under in the past.

The transition from conventional instrumentation to an instrument as complex as the AP-2 will not be an easy one for most organizations. Because it is a superior tool, it requires superior trained people and organization to operate it if all its capabilities are to be realized. Where as in the past, A-7, stereo planigraphs, etc., could be set up in a room to operate in an independent self sufficient manner, plant organization and management must now realize that such isolation is not practical as far as the AP-2 is concerned. Integration with other plant facilities is a necessity in order to make full use of computer, photographic and analytical processes which can support the unique capabilities of this instrument.